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TELECOMMUNICATIONS TIA INDUSTRY ASSOCIATION

Eric J. Schimmel
Vice President

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FEDERAL COMMUNICATIONS COMMISSION
OFFICE OF THE SECRETARY

Mr. William F. Caton
Acting Secretary
Federal Communications Commission
1919 M Street, N.W.
Washington, D.C. 20554

Re: PR Docket No. 93-61
Automatic Vehicle Monitoring Systems

Dear Mr. Caton:

The Telecommunications Industry Association (TIA) hereby requests that the attached correspondence between Dr. Jay Padgett, Chairman of its Mobile & Personal Communications Consumer Radio Section, and Ms. Cynthia Czerner of PacTel Teletrac, be included in the file of the above docket.

Please contact the undersigned if you require additional information.

Sincerely,

Eric J. Schimmel

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List ABCDE

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Representing the telecommunications industry in association with the Electronic Industries Association

November 24, 1993

Cynthia S. Czerner
Vice President, Corporate Development
PacTel Teletrac℠
9800 La Cienega Blvd., Suite 800
Inglewood, CA 90301-4420

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FEDERAL COMMUNICATIONS COMMISSION
OFFICE OF THE SECRETARY

Dear CZ,

This is in response to your letter of yesterday (enclosed). I will address the issues you raised about the interference analysis, and then discuss interference field testing, in which we continue to have an interest. First, however, there are some points in your second paragraph that warrant a response. You express surprise upon learning of our 10/22 visit to the Commission following our 10/19 Section meeting, and our sharing of the interference analysis with Mr. Haller. Given the short time between the Section meeting and the FCC visit, I saw no point in contacting you until after we had received some feedback from Mr. Haller, since we had already shared with you the substance of the analysis during our meeting at TIA October 5. We felt that Mr. Haller should have the benefit of a similar discussion. Your statement that we are "misleading the Commission" with this information (p. 2 of your letter) is unfounded, as discussed in detail below.

The following comments address point by point the issues you raised about the interference analysis.

- You point out that the Teletrac system has redundancy; I assume you mean redundancy in site deployment, plus retry capability (i.e., time diversity). Obviously, such measures will in general protect the system against sporadic, occasional interference. However, when the interference becomes chronic and widespread, its effect on the performance of your system can take several forms. Interference to a given site that is more or less continuous can essentially remove that site from service. If this occurs at several sites, there may be locations in which vehicles can no longer be located. Interference that occurs with some fractional duty cycle (such as from a single frequency hopper) will clearly reduce the throughput of the affected site due to the need to retransmit, thereby reducing the system capacity. It seems to me that this possibility cannot be dismissed. As discussed in the paper, the severity of the problem increases as the number of frequency hoppers increases.

- You suggest that interference among Part 15 devices themselves would tend to limit their deployment density, and hence their ability to pose a threat to your system. This is untrue for two reasons. First, it is possible, and even likely, that two Part 15 devices can have a clear line-of-sight path to one of your receiver towers while having a highly obstructed path between them, because of the elevation of the towers. They also can be further from each other than from the tower (e.g., on opposite sides of a circle surrounding the tower). Second, many Part 15 devices are designed specifically to cope with the hostile interference environment that is anticipated in the 902-928 MHz band (e.g. RF arc welders and plywood heaters). For example, AT&T's frequency hopping technology (used for both cordless telephones and wireless business telephone systems) automatically replaces frequencies on which collisions occur with new, randomly-selected frequencies (in accordance with 47 CFR §15.247). I have done extensive analysis and simulation of the effectiveness of this scheme, and have concluded that a fairly large number of hoppers can harmoniously coexist within a small area without any central control. Further, the frequency replacement mechanism provides some protection against the hoppers interfering with other Part 15 devices that use different formats (e.g., direct sequence systems).* As required by §15.247, the frequency hopping pattern is randomly selected upon initialization, so there are no special "synchronization frequencies." Presumably, the adjacent-channel interference and "poor frequency discrimination" you mention refer to the fact that practical IF filters have finite rolloff that allows some energy from the adjacent channels into the IF. To my knowledge, this is not peculiar to low-cost Part 15 devices, but rather exists in virtually every portable communications receiver (including cellular telephones). Adjacent-channel interference is not a major issue; 20 to 30 dB of adjacent channel isolation is perfectly adequate to prevent significant capacity degradation in a frequency-reuse system. This degree of isolation is readily available with low-cost, off-the-shelf ceramic filters.

You are correct that the processing gain built into most Part 15 direct sequence (DS) systems is not adequate to cope with a strong random interfering signal. However, DS systems designed for robustness in the 902-928 MHz band typically also have frequency agility, allowing them to move away from the

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* Unfortunately, this mechanism will not protect Teletrac's system because the transmitted signal from the vehicle is of very short duration (on the order of 10 milliseconds) and broadband (so most of the energy falls outside the passband of the frequency hopping receiver). In addition, the signal received by the Part 15 device often will be quite weak due to the large path loss between the vehicle and the Part 15 device (both will typically be near ground level, so the path between them will be highly obstructed).

interference. Further, a well-chosen set of spreading codes (low or zero cross-correlation) will allow multiple DS units of the same system to share a band with little or no mutual interference.

Because of the above considerations, I disagree with your view that Part 15 interference will be self-limiting.

- You dispute my conclusions about the effect of the receiver threshold. I believe that this reflects an incomplete understanding of the analysis, so I will attempt to clarify. Any receiver (spread spectrum or otherwise) will have a "threshold" value of E_b/N_0 below which performance does not meet the objectives. If N_0 is constant (i.e., independent of bandwidth, which is the usual assumption), then as the message duration decreases (to increase capacity), E_b decreases proportionally. For a fixed bandwidth, if your receiver is operating above threshold, the rms time-of-arrival (TOA) estimation error varies as the inverse square root of E_b, and hence as the square root of the capacity. Since the rms TOA estimation error also varies as the inverse of bandwidth, you can compensate by increasing the bandwidth as the square root of the capacity increase, keeping the rms TOA estimation error constant as capacity is increased. This gives the familiar (and misleading) relationship that capacity can be quadrupled by doubling bandwidth. However, below threshold, the simulation results reported in Teletrac's Petition for Rule Making suggest that for Teletrac's receiver, the rms TOA estimation error varies as the **inverse squared** of the message duration (this is shown in the paper), so it increases as the **square** of "capacity." Hence, bandwidth must be increased fourfold to maintain a constant error when capacity is doubled.

  One might think that if your system is designed to operate above threshold by some margin, the "bandwidth squared" capacity increase holds. This is misleading, however, because the maximum capacity must be computed under some assumed set of system design parameters, including carrier-to-noise margins. If you presume to quadruple the maximum capacity by reducing message duration by a factor of four, you have reduced E_b/N_0, and hence your margin, by 6 dB, and you have a system with a different set of design parameters. This tradeoff is nothing new; in any multiple-access system for which performance must be characterized statistically (cellular, for example), the nominal capacity can be increased by reducing the performance margins. In other words, you can serve more subscribers by reducing the quality of service per subscriber (e.g., higher blocking probability, greater rate of dropped calls, etc.). Hence, the "bandwidth squared" capacity increase is simplistic and ignores a fundamental set of design tradeoffs.

Hopefully this clarifies your understanding of the points you raised. If any of this still is unclear I would be glad to discuss it further.

Regarding the interference tests, I feel confident in saying that interest in the tests is not limited to the cordless telephone industry, but rather includes representatives of a number of other Part 15 industries. While I understand your concerns about the potential for confusion in working with the Part 15 industry as a whole rather than with small sub-categories individually, I believe that the benefits of pooling our engineering resources and exchanging ideas outweigh the difficulties associated with the large number of participants. Equally important, the methodology, results, and conclusions will have the endorsement of a large cross-section of the industry and therefore will be more credible than a limited "special case" test. I disagree with your belief that such a representative experiment is necessarily time-consuming. I certainly am not proposing to test every Part 15 device in existence; that probably would be impractical. What I *do* suggest is that we develop an experiment that is reasonably representative of most types of expected interference. With the right program structure, this can be accomplished in a timely fashion. Moreover, it would seem most efficient to address all relevant aspects of the problem in parallel rather than serially.

Therefore, as a first step I propose a meeting of interested parties to plan the program. I envision this as a one-day session during which the program and schedule for the test will be agreed upon, including a list of participants and any necessary confidentiality arrangements. To facilitate this process, I have taken the liberty of drafting some notes outlining a "straw man" test plan (also enclosed) which can provide an initial focus for discussion at the meeting. Any comments on this draft prior to the meeting are also welcome.

I continue to believe that if we do not allow Part 15 interests other than cordless telephones to be involved in this, the results will necessarily be inconclusive and subject to challenge from those who are excluded. I therefore encourage you to reconsider your position and agree to participate in such a program in cooperation with ourselves and other Part 15 interests.

Finally, I would like to caution you regarding any inferences you might draw from your limited experience with Part 15 interference to date. While the penetration of Part 15 devices may be relatively low now, it is increasing, and we expect that trend to accelerate as manufacturers complete their designs and deploy products. Hence, the past is not a reliable predictor of the future in this case.

I look forward to meeting with you and other interested parties to discuss these tests.

Regards,

Jay E. Padgett
Chairman, TIA MPC
Consumer Radio Section

enclosures as above

cc: (w/enclosures)

Daniel L. Bart - TIA
Ralph A. Haller - Chief, FCC Private Radio Bureau
Steve Schear - Chairman, Part 15 Coalition
Eric J. Schimmel - TIA
Thomas P. Stanley - Chief Engineer, FCC

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PACTEL
TELETRAC
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Cynthia (CZ) Czerner
Vice President
Corporate Development

November 23, 1993

Mr. Jay Padgett
Chairman, TIA Mobile & Personal Communications
Consumer Radio Section
Fax: (908) 834-1836

Dear Jay:

This letter responds to your letter dated October 28, 1993. I apologize to you for my tardy response. As I mentioned to you by telephone, the delay was caused by my responsibility for business planning, which has consumed all of my time for the last month. Unfortunately, we only have limited resources at Teletrac. I go to sleep at nights dreaming of hiring a big staff!!!

Jay, I need to say at the outset that I was extremely surprised to read your letter for a number of reasons. After Yair and I met with your section at the TIA, I called you to inquire as to whether there were any next steps, and whether you wanted us to test our theory that cordless telephones and Teletrac can live in harmony. You said that you were having a full section meeting, and would contact me after that had occurred. Therefore, you might understand my surprise to receive a letter that stated that you went to the FCC's Private Radio Bureau with a paper showing your theory that we cannot share.

Your paper contains some basic inaccuracies that led you to wrong conclusions. Our engineers have itemized a few of the key points, which we would be happy to sit down and discuss with you in greater detail. These points are as follows:

- The Teletrac system has built-in redundancy. Temporary interference at any level to a few sites does not prevent it from servicing customers.

- The scenario used for the analysis is unrealistic. You create a scenario in which Part 15 devices themselves would not be able to operate. If Part 15 devices start transmitting high energy in line-of-sight from our sites, they would also be in line-of-sight of each other, and at significantly shorter ranges. Since these low cost devices have poor frequency discrimination, the compound effect of in-band interference and adjacent channel interference would prevent all of them from operating. Thus, frequency hopping devices like your cordless phones would find their synchronization frequencies jammed, and they would not be able to initiate communication; or, if they succeeded in synchronizing, more of their frequencies would be interfered with by other devices and the error rate would exceed any error correction threshold. Therefore communication would be lost. Direct sequence spread spectrum devices would find that even a few line-of-sight emissions from other Part 15 devices would raise their perceived noise level to above what their limited processing gain can cope with, and communication would be lost.

- The assumption that a receiver threshold is the limiting factor in TOA measurement is wrong. Unlike radars, well designed terrestrial radiolocation receivers do not require detection thresholds. The determination of the range in which a radiolocation receiver has to provide TOA readings is a system design parameter. The receiver is optimized for the range where its readings are valid. There is no technological limitation in providing readings in a system with twice the Gabor bandwidth and one quarter the total energy (i.e. 1/4 the power-time product), allowing for a fourfold increase in capacity for the same transmitted power.

These are just some of the major points. There are others. Again, let me stress that we would be happy to sit down and talk with you regarding your submission. It is unfortunate that Yair and I were not shown your paper in advance of the submission to the FCC because I think that many of these concerns could have been resolved without misleading the Commission.

Let me also repeat our offer to test whether cordless telephones and Teletrac can live in harmony and our commitment to move forward quickly with the test. We are not willing, however, as you suggested, to have a test that includes every type of Part 15 device that is either on the market or in development. Just getting everyone involved to agree on the test scenarios would take over a year. The test itself would probably take at least another year. We do not have the time nor resources to devote to such a test, and the public interest would not be served by such a delay. We have a living test that has gone on for years, and that is a real life test of existing in the same spectrum with Part 15 devices. It is a rare occurrence that we have a problem with a Part 15 device.

If you continue to be interested in testing cordless telephones and the Teletrac system, please give me or Yair a call. We believe that we can agree on a test and execute it within the next two months. Please bear in mind, however, that you will have to disclose some information that you might regard as proprietary in order to accomplish the test. We, however, would be pleased to sign a confidentiality agreement with you, and assume that you will do the same with respect to Teletrac's proprietary information.

Yair and I look forward to working with you.

Yours truly,

Cynthia S. Czerner
Vice President

cc: R.A. Haller- Chief, FCC/PRB
E. J. Schimmel - TIA

Kathleen Abernathy
Yair Karmi

NOTES ON POSSIBLE PART 15/TELETRAC INTERFERENCE TESTS

Introduction

The purpose of the set of tests proposed here is to develop a quantitative understanding of the potential for interference from Part 15 devices into the receivers used in PacTel Teletrac's vehicle location system in the 902-928 MHz band.

There are several components that determine whether harmful interference occurs:

- The performance of the Teletrac receiver (e.g., rms time-of-arrival estimation error as a function of various desired and interfering signal levels).
- Propagation path loss for various scenarios of interest (different transmitter and receiver elevations, separations, and terrain characteristics).
- Timing characteristics of the interfering signal and the Teletrac reverse link. For example, a frequency-hopping Part 15 device will not always be transmitting within the RF bandwidth of the Teletrac receiver, and the Teletrac system can re-transmit if the received signal is too corrupted.

Each of these components is discussed individually below.

Teletrac Receiver Performance

The function of the Teletrac receiver is to generate an estimate of the TOA (time of arrival) of the wideband burst from the vehicle. One way of quantifying receiver accuracy is the rms TOA estimation error. The rms error depends on the carrier-to-noise or carrier-to-interference ratio, as shown in Figure 12 of Appendix 2 to Teletrac's Comments on the NPRM in PR Docket 93-61, attached here as Fig. 1.

The first step of the experimental program should be a more complete characterization of the Teletrac receiver. The curve in Fig. 1 characterizes the receiver only for a carrier-to-noise ratio (CNR) down to -25 dB, and the noise power was set at -80 dBm. The TOA estimation error should be determined for CNR levels less than -25 dB (which apparently is the threshold of the Teletrac receiver). The error also should be measured as a function of the CNR for higher noise power (e.g., -40 dBm), to explore AGC and A/D dynamic range effects.

The receiver performance characterization probably is the most important component of the experiment, since the effects of the other two factors (propagation and timing characteristics) can easily be investigated via analysis and/or simulation. Fortunately, receiver performance measurements can be made on the bench, using known and controlled desired and interfering signals.

A further step would be to introduce multipath effects into the bench test via a fade simulator, to characterize the impact of different multipath delay profiles on the rms TOA estimation error.

Propagation Path Loss

Path loss is important because it determines the strength of the desired and interfering signals received by the base station. The technical literature is rich with papers discussing propagation phenomena and models for a wide variety of frequencies, terrain conditions, and applications. Empirical models have been developed based on analysis of measurement data, and models also have been built directly from electromagnetic theory. In most circumstances, propagation path loss must be viewed statistically because of the random factors (multipath, shadow fading) that influence it. Because of this statistical nature, measurement programs typically involve many thousands of individual data points to accurately characterize propagation behavior. As a result, they tend to be fairly tedious and time-consuming, and require a certain degree of specialized equipment and expertise to perform reliably.

To draw general conclusions about the interference problem, we probably should use some of the existing propagation models based on the published work of experts in the field. The alternative is to conduct our own propagation measurement program, which would be time-consuming and probably not very enlightening. Of course, if we conduct field tests, we will need to make isolated measurements of the received signal strength for specific paths to determine the levels of the desired and interfering signals, and we should note the approximate distances from the receiver of the desired and interfering transmitters.

Timing Factors

If the interfering signal does not continuously overlap the Teletrac reverse link passband, then "time diversity" (re-transmission) can help to mitigate the effects of interference (although it will reduce throughput). Time diversity may work if the interfering device is a frequency hopper, but the relationship between the re-transmit interval and the hopping rate will be a factor. If there are multiple hoppers near multiple bases, the statistics of the problem rapidly become quite complicated and will be difficult to characterize fairly with a simple experiment. However, analysis of the situation would be fairly straightforward once all the parameters are known. Therefore, measurements should use a continuous interfering signal to determine the inherent receiver susceptibility, and transmission timing should be taken into account by analysis.

Conclusions

The first part of the test program should be a more thorough characterization of Teletrac's receiver. Without this, it may be difficult to correctly interpret field test results. Such a characterization should be fairly straightforward on the bench using an approach similar to that described by Teletrac in Appendix 2 of its Comments. However, the effects of a larger range of CNR and higher noise (and carrier) power need to be explored. In addition, multipath effects could be introduced using a fade simulator. If time is extremely critical, many useful and valid conclusions could be drawn from such measurements using existing propagation data and models. If time allows, field experiments of interference effects associated with different interfering and desired signal source positioning could be conducted. The strength of the interfering and desired signals at the receiver should always be measured, so results can be checked against the receiver bench tests.

The effects of time-diversity and fractional duty cycles of the interfering signals (such as those from frequency hoppers) will be difficult to characterize completely with experiments, but can be understood easily with analysis. Therefore, the field tests should use fixed-frequency transmitters to simulate the interference sources. The results can easily be extrapolated to account for time variations.

POSSIBLE PROGRAM OUTLINE

Based on the considerations discussed above, one possible set of steps is:

1. Assemble interested parties, review proposed plan, add detail, determine participants, develop schedule.
2. Conduct bench tests of Teletrac's receiver for CNR ranging from -15 dB to -40 dB and noise from -40 dBm to -80 dBm in 5 dB increments (no multipath).
3. Repeat (2) but introduce multipath with a fade simulator. Explore effect of multipath for delay spreads up to 25 μs. Make detailed measurements over a range of CNR for cases of interest. [More detail to be added during planning meeting.]
4. Select a single Teletrac receiver site that will allow a controlled variation in the positioning of both the interfering and desired signal sources. Set up a test control system that will allow the desired transmitter (in a vehicle) to repeatedly transmit its signal on command. This will allow enough samples to be taken to support a statistically valid determination of the rms TOA estimation error. Received signal levels for the vehicle and the interference source should be recorded. Take sample sets of TOA estimation error and signal strength measurements for desired positions of vehicle and interference source. [Details of test conditions to be added during planning meeting.] Note: with the complete bench characterization of the receiver, and knowledge of the path loss characteristics for the scenario of interest, these measurements are not completely necessary, but they may serve as useful confirmation of predicted results.
5. Share relevant information on timing characteristics of potential interference sources, and retransmission (time diversity) discipline of Teletrac's system. Using this timing information and the results of the tests discussed above, compute the effect of interference on system throughput for scenarios of interest.
6. Prepare report summarizing problem, outlining general approach, reviewing procedure and equipment, showing data, summarizing results/conclusions, and identifying any remaining open issues.

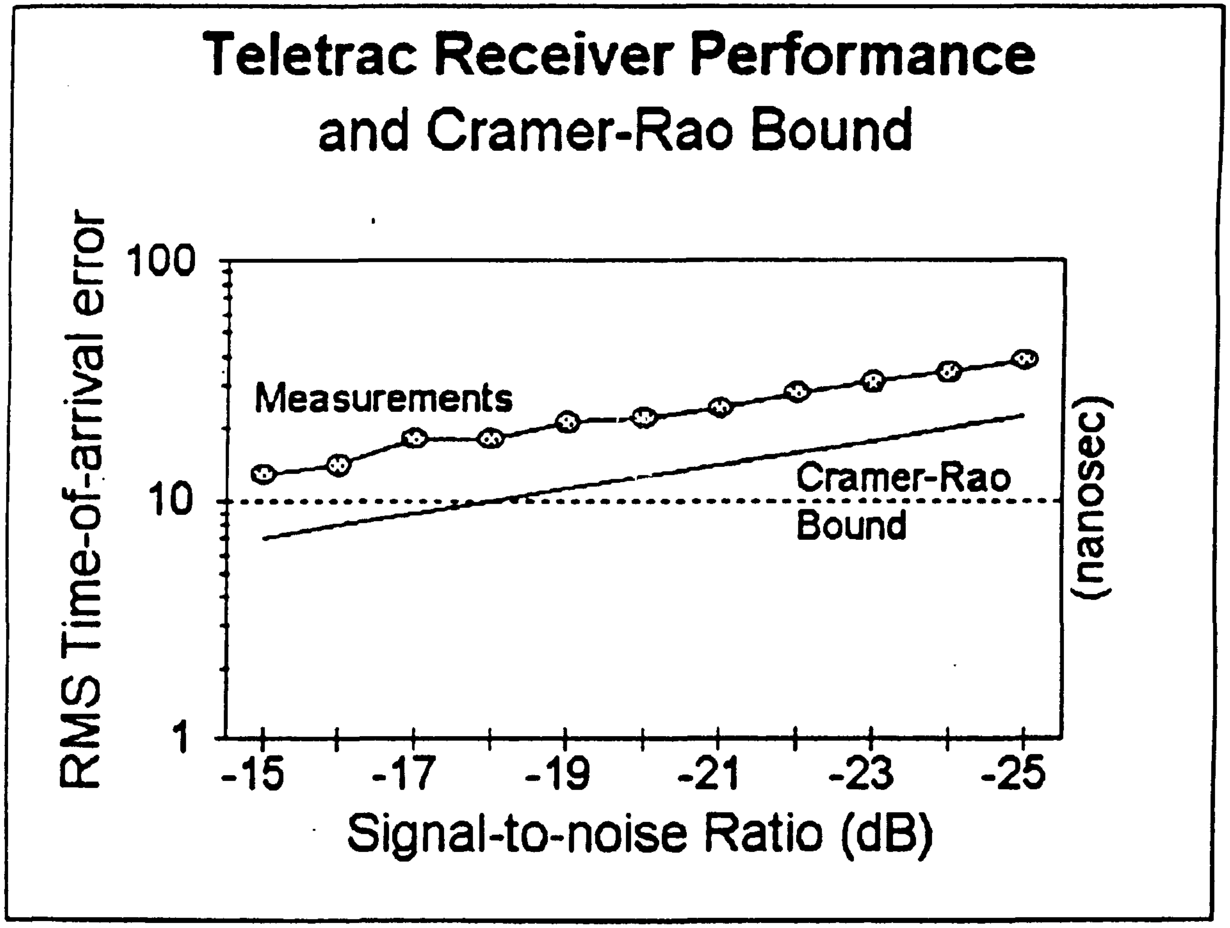

Figure 1

(reproduced from Appendix 2 of Teletrac's Comments, Fig. 12)